white spot behind the eye; prothorax slightly corrugated in the centre, a broad yellowish-white line on each side and a narrower one beneath; scutellum transverse, black; elytra acuminate, finely punctured, pale brown, with two longitudinal whitish lines on each, united at the shoulder and apex; antennæ and legs pitchy, the former nearly three times the length of the body, the femora reddish at the base; body beneath with a greyish pile. Length 7 lines.

Cylindropomus should, I think, be placed in the Lamiidæ, near *Olenocamptus*, from which, indeed, it scarcely differs. A series of this species shows a very considerable amount of variation in the width of the head: in some it is scarcely wider than the prothorax, and from these it runs up to nearly twice the width.

XIII.—*On the Markings of the Diatomaceæ in common use as Test-objects.* By G. C. Wallich, M.D.

The markings on the valves of certain species of Diatoms have long been prized as tests of the defining and amplifying powers of microscopic lenses. Up to a very recent period they answered every purpose; but the rapid advances achieved of late by our leading opticians in the construction of objectives furnish us with many instances in which the formerly received interpretation of minute organic structure has turned out to be fallacious. These tests have thus been somewhat unduly valued, and, as a natural consequence, many indifferent objectives have been thrust on the public, the efficiency of which depended, not on accuracy of construction, but on the variable nature of the tests they were subjected to.

Accuracy of measurement is of the first importance in all microscopic investigations, whether we desire to measure the striæ on a Diatom, the thickness of a cell-wall, a blood-disk, or any of the numberless objects the microscope reveals to us; and until this perfect accuracy is ensured, it is almost needless to say that a vast amount of time and patient labour will be expended in vain.

As an example in point, we need only take the value of *Pleurosigma fasciola*, a Diatom which was considered, until a very late date, as one of the severest tests for a first-rate $\frac{1}{8}$ or $\frac{1}{12}$ objective. It is true that *P. fasciola*, under certain restrictions, may be made an admirable test; but it is one adapted with equal propriety to test either a $\frac{1}{2}$ or a $\frac{1}{12}$ objective. This is due to the widely varying character of its lineation,—a fact of which the less scrupulous class of opticians were not slow to avail

themselves, in order to arrogate for their workmanship a degree of excellence it in nowise merited.

It should be borne in mind that the mere number of lines in any given fractional portion of an inch is not all that is required in a Diatom employed as a test. Much depends on the particular conformation of the Diatomaceous valve—on its thickness, flatness, the angularity of its markings, their direction, the kind of illumination, and so forth. But this only tends still further to diminish the value of such objects as tests, inasmuch as the same form, under different conditions, may or may not be suited to test a given combination.

It is not my province to discuss how much valuable time is often wasted in the endeavour to resolve markings on Diatoms or other minute objects, that might be applied to higher and far more useful purposes. It is well known that many ardent observers labour, for days and even weeks together, in order to conquer some difficulty of the kind,—their toil ending in failure simply because they are unaware that the same species of test-Diatom may present itself under such modifications as to baffle all attempts at resolution in one shape, whilst it may be made to yield readily in another. At present the capabilities of lenses have, too frequently, to be discovered after purchase. They may or they may not come up to the professed standard. The owner may apply an incorrect or an insufficient kind of test; and, under any circumstances, he is unable positively to assure himself of the real power of the apparatus he is using.

Certain Diatoms may still be advantageously employed as test-objects, but assuredly not in the manner hitherto in vogue. In order to ensure uniformity, or, what amounts to the same thing, in order to ensure the purchaser of a lens of a stated power actually obtaining what he desires, it becomes essential that each test-slide should itself be compared with some accredited and universal standard, before being applied to the decision of the capabilities of any optical combination.

I shall endeavour presently to show how likely we are to be misled in our estimate of lenses based upon the resolution of some of the ordinary tests, by giving a tabular statement of the range of lineation admitted to exist by those who have given the greatest amount of attention to the markings on the various test-Diatoms. In dwelling on this topic I have an important purpose in view, namely, the introduction of a definite and uniform standard test, for each grade of objective, in lieu of the indefinite and variable ones that have heretofore been in use.

M. Nobert's test-glasses at once suggest themselves to our notice as likely to afford the requisite standard. We have here a degree of minute workmanship destined for ever to defy the

unaided eye, and demanding the highest of our optical aids to render its nature manifest. These glasses have certainly met with little encouragement in this country; but this depends on no fundamental error either in M. Nobert's principle or his handiwork, but on a minor defect, which will, without doubt, be speedily overcome. I allude to the difficulty of engraving the different series of lines on slips of glass sufficiently thin to admit of their employment under the highest and most delicately adjusted combinations of the microscope. It is universally allowed that the accuracy of the lineation cannot be surpassed, the last and closest series of lines being as regular and distinctly ruled as the first or most distant. The difficulty can hardly be overcome, however, until a separate slip of glass is devoted to each two of the first five or six series, and each one of the remaining number. This would, of course, enhance the cost to a considerable extent; but a truly effective standard would be the result, and we should establish a check upon the fallacious test-objects hitherto resorted to. It must be evident that the more perfect our instruments become, the more urgent is the requirement for an undeviating standard of comparison. When this is known to exist, purchasers of lenses will be provided with a safeguard; and, as a necessary consequence, the efforts to produce improved apparatus will be redoubled.

The subjoined Table gives the lineation of some of the commonly employed test-species, according to the authorities noted in the first column. M. Sollitt's measurements, it will be seen, embrace the extreme ranges. The accuracy of his figures is unquestioned, as regards all but the two last-named forms on the list; and in these it has met with scepticism solely from

Tabular Statement of Lineation in 1000*th of an inch.*

Authorities.	Pleurosigma angulatum.	Pleurosigma fasciola.	Pleurosigma quadratum.	Pleurosigma formosum.	Pleurosigma balticum.	Pleurosigma hippocampus.	Pleurosigma strigosum.	Navicula acus.	Navicula rhomboides.
The 'Synopsis of Brit. Diatomaceæ.'	52	64	45	36	38	Lo. 32 Tr. 40	44		
Carpenter*.....	52	64	...	...	...	Lo. 30 Tr. 40	44	...	85
Micrographic Dictionary.	52	64	45	36	38	Lo. 30 Tr. 40	45	125·130	85
Sollitt†	46·51	50·90	35·60	20·32	20·40	40·45	40·80	120·130	60·111

* 'The Microscope,' by Prof. Carpenter, p. 205.

† Quarterly Journal Microscop. Science, No. 29, p. 51.

the extreme difficulty of counting lines so delicate, even granting them to be visible under the lens. Accepting the measurements as approximately correct, it is apparent that a series of markings, the variation of which, in the several species, ranges from about 5 to 50 per cent., ought no longer to be received as affording standard tests or specific characters.

I have stated that the hitherto received interpretation of various structures, as seen under the microscope, has in many cases turned out to be inaccurate, owing to the improved means of observation at our command. I would draw attention more especially to one of the most valuable, inasmuch as it is the most constant in its lineation, of all our test-Diatoms, viz. *P. angulatum*. It is well known that, under the generally adopted view, the markings consist of hexagonal *depressions* on the surface of the valve. Not only has this interpretation been insisted on by all our chief authorities, but its accuracy has been made to appear unimpeachable on the evidence afforded by a photographic image. Facts are stubborn things to contend against; and in an endeavour to correct an impression based on such apparently incontrovertible testimony I am painfully aware that I have a hazardous task to perform.

Professor Carpenter ('The Microscope,' p. 304) writes as follows:—

"In the first place it may be remarked, that there is a much greater uniformity in the general character of these markings than was supposed when attention was first directed towards them; for what were at first supposed to be *lines* are now resolved by objectives of large angular aperture into *rows of dots*; and these dots, when sufficiently magnified, are found to bear a close resemblance to the coarser markings on the larger species. It is to the latter, therefore, that we should have recourse for the determination of the nature of these markings; and we cannot resort to better illustrations than those that are afforded by *Isthmia*, *Triceratium*, and *Biddulphia*, in all of which the structure of the valve can be distinctly seen under a low magnifying power, and with ordinary light." After proceeding to show that the markings, in each of these instances, consist of a number of areolar depressions, he continues: "Now, it would not be difficult to bring together a connected series of Diatomaceæ in which the markings, still exhibiting the same general aspect, become more and more minute, requiring for their resolution the use of oblique light, or stops with a central diaphragm, and of objectives of larger and larger angular aperture, until we come to those species which present the greatest difficulty, and the nature of whose markings seems to be most obscure. The more perfectly these markings are defined, however, in any

case, the more decidedly are they found to correspond with what has been already seen. Thus, if we examine *Pleurosigma angulatum* (one of the easier tests) with an objective of $\frac{1}{4}$ inch focus and 75° aperture, we shall see a double series of interrupted lines, crossing each other at an angle of 60°, so as to have between them imperfectly defined lozenge-shaped spaces. When, however, the valve is examined with an objective of $\frac{1}{12}$ inch focus, having an angular aperture of 130°, and is illuminated by oblique rays, the hexagonal areolation becomes very distinct; and if a photographic representation obtained by such a power be itself enlarged by photography, as has been accomplished by Mr. Wenham, the appearance represented (by the diagram, *loc. cit.*) is obtained, which is in all respects comparable with that presented under a low power by the valve of *Triceratium* or *Isthmia.*"

In the 'Micrographic Dictionary' we find observations nearly to the same effect. But a remarkable paragraph occurs at page 221 (new ed.), in the article "Diatomaceæ." After denoting the varying phases a Diatomaceous valve may be made to assume under different powers and modes of illumination, it thus concludes:—"If the condenser and stop be not exactly centrical, or the surface of the valve be not flat, the true form of the dots will be replaced by some other: thus hexagonal dots may be made to appear triangular, quadrangular, &c., and those dots which cannot be conceived to be really hexagonal may be made to appear so,"—*Pleurosigma balticum* being here referred to amongst the figures.

I duly appreciate the difficulty of having to deal with statements supported by such unquestionably high authority,—more particularly when they seem to carry with them the proof derived from the photographic art. But the latter testimony appears to me by far the most assailable, and I have adduced the paragraph just quoted in support of my assertion. For if, by modification in the focussing of a valve, hexagonal dots may be made to appear triangular or quadrangular, and those dots which cannot be conceived to be really hexagonal may be made to appear so, it follows that by similar modification under the photographic appendage to the microscope, these figures may be respectively reproduced according to the fancy of the operator.

Although the evidence derived from a photographic picture may safely be relied on under ordinary circumstances, it at once loses its value in the case before us, the image thrown on the prepared plate or paper being of necessity identical with that impressed upon the eye of the observer when adjusting the object to be depicted, and whatever he sees being, as a matter of course, reproduced in the photographic picture.

Now, every authority with whom I am acquainted starts off by admitting as an axiom that the lower the power under which the structure of any object can be made evident, the less chance is there of error. To dispute this would be absurd. The same authorities admit, moreover, that under a moderate power (say of from 300 to 500 diameters) the lineation of *P. angulatum* appears in the form of obliquely or diagonally arranged lines, placed at an angle of about 60° with the transverse section of the valve, and enclosing "lozenge-shaped" spaces between their intersections. And, strange to say, in some of our most elaborate works, the greatest pains appear to have been taken to show the beautifully defined character of these lines, under the powers just indicated, even to the extent of employing specially prepared polished paper for the engravings which represent it.

Analogy has been pushed a little too far in this instance. There are cogent reasons, open to every observer of the Diatomaceæ, why we ought not to expect the same markings in the Naviculoid as in the discoidal and allied forms. It would be vain, for example, to endeavour to reduce such as are found on *Surirella* or *Pinnularia* to the same category as those of *Isthmia*, *Biddulphia*, or *Triceratium*. No forms can be more distinct in this respect than these last named. Their typical structure, as observed in *T. favus*, consists of *depressed* spaces, which vary from true hexagons in their horizontal section to somewhat irregular figures, such as we find in *Eupodiscus Argus* and *Isthmia enervis*, where, in addition to mere irregularity in outline, the walls of the depressed spaces are studded with minute projections, giving them a ragged appearance under sufficiently high magnifying power. In pressing either of these into our service, therefore, simply because they are of dimensions large enough to be most readily dealt with, a serious error has, in my humble estimation, been committed. But it is a remarkable fact that *T. favus* actually supplies us with markings strikingly similar to those of *P. angulatum*, not on its valves, but on its connecting zones. A very little care is requisite, in the case of the larger varieties, to show that the markings of this portion of the frustule are, as in the case of *P. angulatum*, *diamond-shaped elevations*, each of which presents four clearly defined facets, inclined to the surface of the valve at an angle probably of about 25°, and yields, therefore, four distinct series of lines, two of which, the diagonal, are most clearly marked, for reasons presently to be given; whereas the other two series (namely, the transverse and longitudinal) are more nearly approximated to each other, and much less palpable.

In using direct light, either with or without an illuminating combination, for the resolution of these markings, it is almost

impossible to succeed. If we look upon an ordinary plano-convex condensing lens, placed at a distance from the eye, in the direct line of the source of light, provided no objects present themselves in the background, the convexity is inappreciable. The moment, however, that an angle is formed by the rays, the convex character strikes us. And so with objects exhibiting angular facets, although in a less easily demonstrable degree, owing to the impossibility of receiving several sets of rays, each parallel to one series of facets. Under the microscope, the same principle holds good: facets are never seen by *strictly* direct light. The mere placing the axis of the instrument in a line with the source of light by no means fulfils this condition. In viewing transparent objects, and more especially objects of such high refractive power as the valves of the Diatomaceæ, oblique light must be engendered. We must in this instance court shadows as our only means of grasping the reality. To exhibit these much coveted "*dots*," shadows are still indispensable, but here they are imperfect ones*. The greater the obliquity of the illuminating rays, *so long as definition remains perfectly clear and free from coloured spectra*, the greater will be the distinctness with which the true character of markings will be seen. Unless they are thus distinctly seen, appearances must prove deceptive, and even the photographic picture may err *in modo*.

In a valuable paper "On Species of Diatomaceæ," under the signature of one of our first authorities (Professor Walker-Arnott, Journal Microscop. Science, vol. vi. p. 200), the following passage occurs:—

"But as all Diatoms, with striæ composed of dots, have four rows of striæ (two diagonal, one horizontal, and one longitudinal), and as the visibility of each depends, when delicate, on the position the valve presents to the illuminating pencil of oblique light, the closer or more difficult striæ are sometimes seen when the others are not, and thus may be occasionally mistaken for the predominating or coarser ones, which alone are made use of in specific characters. I may here remark that, when the dots are so placed as to form rectangles, the transverse and longitudinal striæ are always the most remote, and therefore predominate; and it is generally supposed that when the dots are quincuncial, the diagonal lines are always most apparent; but

* In a paper by Hugo von Mohl (in the December Number of the Annals and Magazine of Nat. History, p. 444) the author is at pains to prove that polarized light has been neglected heretofore in microscopic examinations; and, in proof of the advantages to be derived from its employment under scientific adjustment and management, he states that the markings on *Pleurosigma angulatum* may actually be shown to consist of "*six-sided dots*."

this conclusion is not correct: for when the diagonal lines make, with the transverse, an angle greater than 60°, the transverse rows are more remote than the diagonal; and when the angle is less than 30°, the longitudinal rows are the more remote, and easily detected. In the quincuncial structure, therefore, the diagonal lines predominate only when the angle of inclination is more than 30° and less than 60°; but the transverse and longitudinal cannot both preponderate in the same species."

I have therefore the satisfaction of believing that my view is borne out, as far as the number of series of lines is concerned, by one so competent to guide our judgment. The cause of the predominance of the diagonal lines in *P. angulatum* and the rectangular in *P. balticum* is thus made apparent to a certain extent. But it will be observed that Professor Arnott evidently considers the whole four series of lines as occurring upon the same plane, the word "distant" bearing reference clearly to the position of the lines as removed more or less from each other on that plane, and the theory offered being, that the more distant series of lines are most distinct, whereas the most closely approximated are the reverse.

Both as regards *P. angulatum*, *P. hippocampus*, and their allied forms, the diagonal series of lines consist of alternate ascents and descents along the angular edges of the raised facets, which thus constitute a series of zigzag lines directly in the line of vision, whereby they cannot be brought simultaneously into focus at all points. In short, every portion of the two series of lines which bound the elevations is arranged on the same plane, whilst the lines which unite the facets are not so.

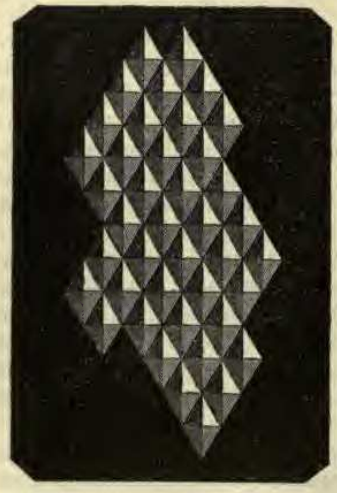
In *P. formosum* and *P. quadratum* the structure is analogous to that existing in *P. angulatum*. In *P. balticum* and *P. hippocampus*, instead of diamond-shaped elevations, we have four-sided flattened pyramids, presenting, as in the former case, four sets of lines; but here, as a natural consequence, the spaces being bound by the longitudinal and transverse series, these predominate.

This is in accordance, moreover, with the lines of fracture observable in both types,—a fragment of *P. angulatum*, for instance, always having its edges defined in conformity with the diagonal lines bounding the diamond-shaped elevations; whereas in *P. balticum* the edges follow the rectangular outline of the boundary lines. In both examples, the lines of fracture occur at the *thinnest* portions of the valves. No such lines of fracture occur in *Triceratium*, *Isthmia*, or *Biddulphia*. Of course, according as we view these objects on their external or internal aspects, the eye receives the impression of elevations or depressions, the markings—*i. e.* the elevated angular spaces—being confined to

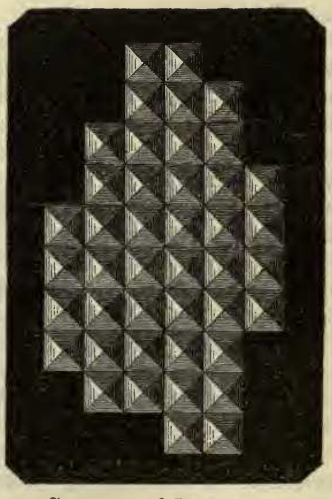
the exterior surface. The "diamond pattern" often seen on household ware of cut glass will at once serve to illustrate the kind of structure in question.

Lastly, whilst we have *four* series of lines in all the Diatoms just alluded to, we have only *three* in such as exhibit true hexagonal areolation; and we cannot, under any modification of light, or adjustment, or magnifying power, convert these six-sided spaces, *so long as they remain clearly defined*, into diagonal or any other kind of lines. Whensoever appearances present themselves under the microscope which are known not to represent the true structure or markings of an object, we may rely upon it that either the instrument or its adjustments are at fault. With perfect objectives and proper adjustments, these spurious appearances cannot occur.

The subjoined admirable woodcuts illustrate, in an exact manner, the structure of the two typical forms, *P. angulatum* and *P. balticum*; and it will be observed that, even on the plane surface of the paper, by altering the position of the figures with



Structure of *Pleurosigma angulatum.*



Structure of *Pleurosigma balticum.*

reference to the source of light, the appearance of elevations or depressions may be imparted to the facets at pleasure. Under proper management, this structure may be made apparent, with equal clearness and definition, either by means of a $\frac{1}{4}$ inch or $\frac{1}{12}$ inch aperture.